Aix Marseille Université

Ecole Doctorale des Sciences Chimiques ED250

Offre de thèse **2025**

Thesis subject
Investigation of aerosol properties in microgravity conditions.
Laboratory : MADIREL, Aix-Marseille University-CNRS, Centre Scientifique de Saint Jérôme, 52, Av. Escadrille Normandie-Niemen 13013, Marseille, France.
PhD Advisor : Mickaël ANTONI
Emails : m.antoni@univ-amu.fr
Starting date : Before november 2025

Background

Aerosols are complex media, sensitive to temperature and pressure conditions, sometimes chemically active, consisting of a continuous gaseous phase in which liquid and/or solid phases are dispersed. They are naturally subject to the influence of gravity, which determines the sedimentation rate of the particles they contain. Aerosols can be of natural or man-made origin. Fog, dust, clays and forest exudates are natural examples, while smog and fine particles (produced by internal combustion engines and heating) are produced by human activity. They find multiple applications in pharmaceutical and cosmetic industry (inhalers, metallurgy (spray drying) and agriculture (pesticides).

Project description

From an academic point of view, aerosols are subject to intense research activity. The description of their evolution is for example a major issue in climatology where important questions are still open in cloud microphysics when investigating evaporation/condensation/coalescence of droplets, evolution of droplets in turbulent flows and nucleation phenomena in supercooled regimes. All these phenomena are actually coupled and may take place simultaneously

The aerosols investigated in this thesis will consist of populations of water droplets similar to those contained in fogs or clouds. But other chemicals, such as methane or compounds of the hydrofluoroether family, will also be used with the aim to understand the formation and evolution of droplets created from gaseous mixtures. The study of such aerosols is essential. Understanding their stability is indeed a key issue in climatology and global warming.

The candidate will carry out experiments in ground conditions and in parabolic flights microgravity conditions. A dedicated experimental device, the rack AEROSOL funded by CNES, will be used for the experiments. The droplets studied, although micrometric in size, are naturally subject to sedimentation due to gravity. When their radius reaches few micrometers, sedimentation velocity becomes too large for reliable description. The characteristic times of droplet-droplet mutual interactions are indeed much longer than those imposed by gravity. Reduced-gravity conditions are therefore essential here and explain why the candidate will be actively involved in parabolic flight campaigns.

Aerosols will be produced in a 43 cm3 experimental cell (EC) and will be generated by an expansion process based on the same principle as in a Wilson chamber. This expansion leads to a fast drop in pressure in the EC, as the air expands in a 105 cm3 compression/expansion chamber (CEC). An optical transmission tomography microscope equipped with a high-speed camera (2000 images/s) is used to follow the evolution of the droplets in a 2 mm3 volume with a spatial resolution of 1 µm. The EC and CEC are equipped with temperature and pressure sensors, and the entire experiment is regulated for relative humidity. Droplet dynamics will be studied by measuring their radius and their velocity. The chemical composition of the gases will be analyzed byFT-IR spectrophotometry. Finally, two motors fitted with rotors will set the aerosols in motion, enabling Von Karman swirling flows and coalescence studies.

Recent parabolic flight results have demonstrated the possibility of producing aerosols stable enough to perform reference experiments and have provided original insights into the evaporation dynamics of droplet populations. But at this stage, no temperature control of the EC has been implemented. Temperature is assumed to be constant over the time scale of the experiments. This thesis will therefore begin with extensive instrumental work to validate a set-up dedicated to this temperature control. This setup will consist of a set of 12 temperature sensors and 12 water-cooled Peltier modules, to be installed in the AEROSOL. The aim is to reach temperatures of -40°C in the EC, with gradients smaller than 0.06 °C. These conditions will be necessary for mass transfer studies between supercooled droplets and iced-droplets. The timetable will also focus on the continuation of previous instrumental developments, including FT-IR spectrophotometric analyses and the control of relative humidity.

The candidate will work in a laboratory focusing on the properties of dispersed systems and on the description of heat and mass transfer mechanisms. He/She should therefore have skills in kinetics and thermodynamics. He/She should also be interested inand motivated by liquid/gas interfacial phenomena, image processing and instrumental developments. Experience in optical microscopy and instrumentation will therefore be strongly appreciated. The candidate will be required to process large quantities of data. An interest in big-data analysis is hence also required.

References

Graziani, C., Nespoulous, M., Denoyel, R., Fauve, S., Chauveau, C., Deike, L., & Antoni, M., Comptes Rendus. Mécanique, 351(S2), (2023), 1-15, https://doi.org/ 10.5802/crmeca.159